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XIII. *On the Nervous System.* By Sir CHARLES BELL, F.R.S. &c.

Received February 24,—Read April 2, 1840.

TWENTY years have passed since the Society honoured me by printing my first paper on the functions of the nervous system. It is thirty years since I circulated a short essay, in which the idea of the new principle which has guided me in my inquiries into this subject was pointed out. The Society will acknowledge that since that time, investigations into the nervous system have been prosecuted with a success strongly in contrast with that attending the inquiries during the long period of some hundred years, in which a false hypothesis had satisfied the minds of the medical profession, and chained down physiologists in inactivity.

In 1821 I had made so much progress in these investigations, that I was encouraged to present my first paper to the Society, as no longer the expression of mere opinions founded on experiments too delicate to be generally appreciated, but demonstrations of substantial facts, easily proved to be correct, and such as the Society has always sought to encourage. After the principle had been once established by anatomy and experiment, that the nerves possess distinct functions in correspondence with their origins from the brain and spinal marrow, time and opportunity were alone wanting for collecting the pathological facts which were to give importance to the observations in these early papers. Those facts I am now desirous of placing before the Society, to complete the subject as far as regards my own labours.

First in regard to

The Spinal Nerves.

In the earliest part of my investigations I performed experiments on the roots of these nerves. I exposed the spinal marrow, separated the distinct roots, and found that the anterior root on being irritated excited motion, while the posterior root did not excite the muscles. By inference, and by comparing the spinal nerves with those of the encephalon, I was at length led to conclude that the anterior root is provided for motion, and the posterior for sensation; and that the spinal nerves, instead of being common nerves, are in truth combined of roots, one of which gives motion and the other sensation.

Many instances have presented themselves in the prosecution of this subject, to show that, until directed by a knowledge of function, we are inattentive to facts of daily occurrence. To take an example, since I had reason to conclude that the columns of the spinal marrow, and the roots arising from them, were distinct in func-

tion, I have met with no instance of disease in the bodies of the vertebræ attended with paraplegia, in which the muscular power of the limbs has not been the first affected: in all, the defect of motion has been greater than the diminution of sensibility; in some, the motion of the limbs has been lost, whilst the sensibility has been exquisitely acute.

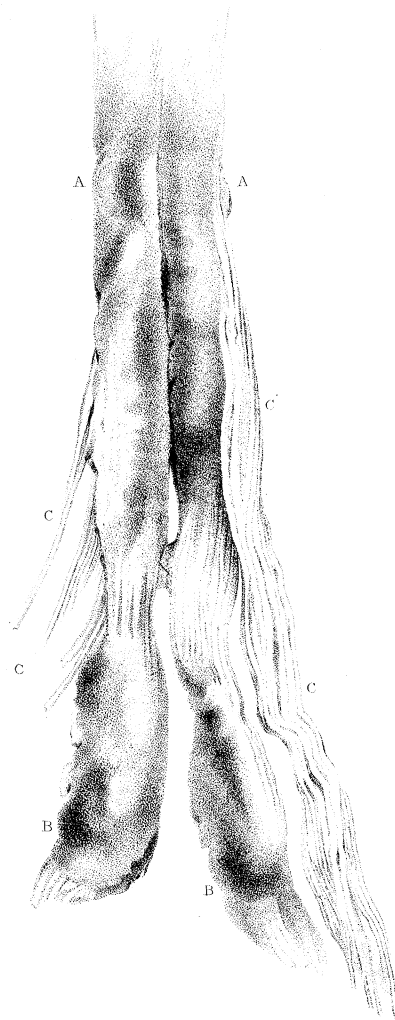
These facts, it is now obvious, are to be accounted for by the motor roots of the spinal nerves being more directly exposed to the influence of the inflammation seated in the bodies of the vertebræ, than the posterior roots of sensation, which arise more remote from the disease.

In a case now before me, there is disease affecting the bodies of the vertebræ of the neck; the arms hang powerless, whilst the sensibility is perfect; and the patient walks stoutly. By looking to the roots of the great nerves of the axillary plexus, in the dead body, the cause of this is manifest; we see that the motor roots cover the spinal marrow, and that, whilst they protect the body of the spinal marrow, they are exposed themselves, by their proximity, to participate in the inflammation of the bone. When a section of the spine and sheath of the spinal marrow is made, especially in the neck or in the loins, it is observed that not only do the anterior roots of the nerves protect the column of the spinal marrow from which they arise, but these roots, together with the *ligamenta denticulata*, whilst they are themselves exposed to the influence of disease in the bodies of the vertebræ, guard the posterior column and sensitive roots. If the inflammation or morbid influence, in this case, had penetrated to the spinal marrow, and had paralysed the muscles of the upper extremities, by affecting that organ, the muscles of the lower extremities would have suffered equally with those of the upper.

The spinal marrow, properly speaking, terminates at the second lumbar vertebra: but the anterior roots of the nerves forming the *cauda equina*, cover and protect the posterior roots from the influence of disease in the bodies of the vertebræ.

The following occurrence will be regarded with interest in connexion with this subject. Plate IX. exhibits a tumour which engaged the anterior roots of the sacral nerves, as they form the *cauda equina* within the tube of the vertebræ. The tumour was of the form of an almond, but larger, and into it, the motor roots, both of the right and left side, were gathered, whilst the sensitive roots were free. The peculiar circumstances attending the case were communicated to me while the patient, who was in the public hospital of Edinburgh, was alive. The lower extremities were deprived of motion, whilst they retained sensibility; and symptoms of so much interest were noted and discussed by the physicians and pupils.

When a tumour on a nerve interrupts the communication between the brain and the extremity of the nerve, and the consequences are observed, they are conclusive as to the functions of that nerve, and afford a proof of them much superior to experiment. When a case of disease in the fifth nerve of the brain presents itself, the insensibility of the side of the tongue, of the side of the face and head, and of all the



Disease of the Spinal Nerves.

A.A. The Spinal marrow divided from behind.

B.B. The tumour on the anterior roots, divided.

C.C.C.C. The Posterior roots of the nerves passing the tumour & free.

cavities with the loss of power in the muscles of the jaw of that side, unequivocally confirm the deductions which I drew from the anatomy, that the fifth pair confers motion and sensation, in correspondence with its rising from the brain by two roots. In such a case, the trunk of the nerve, consisting of the united roots, is affected; and the privation of function is complete. In the present instance, the motion alone of the limbs was lost, by the destruction of the anterior roots of the nerves; whilst the sensibility remained, owing to the posterior roots being unaffected.

I am unwilling to enter on so great a subject as the influence of the cerebellum, and of that posterior column of the spinal marrow which descends from it. Important as these parts must be in the œconomy, there are no facts to countenance the belief, that they are directly connected with the functions of motion and sensibility. Indeed the posterior column of the spinal marrow has been found softened to a degree, which we must suppose inconsistent with the continuance of its functions; and yet sensibility has been entire. But let not this fact militate against our conclusions. The column in the spinal marrow which gives rise to the sensitive roots, is posterior to that from which the motor roots arise; but is not the posterior portion of the spinal marrow. Some have imagined, from finding the posterior column of the spinal marrow softened, in cases where sensibility was entire during the life of the patient, that they had found an argument unfavourable to our general conclusions.

In consideration that the results of the experiments on the roots of the nerves of the spine, first made thirty years ago, have thus been confirmed by pathology, the Society will perhaps permit me to state how I was induced to commence these experiments. In thus adverting to my early investigations, I am only desirous of showing the principle which guided me in these pursuits.

Some of the physiologists, at home and abroad, who have treated of this subject, have appeared to consider the facts brought out by the experiments on the spinal nerves, as accidental results. Misconceiving the just application of experiments to this inquiry, they have made it a boast, that they proceeded to their experiments without preparation; and have gone so far as to represent the person who dissects living animals, indifferent to the results, and only curious to find something new, as the true philosopher! However this may be, my experiments on the spinal marrow and roots of the nerves were not undertaken till after long consideration and much minute dissection. Many of my pupils, now risen to eminence, may remember that at the time alluded to, my lectures on the nervous system extended beyond what was customary in the courses delivered in London: not trusting to preparations, minute dissections were made for each lecture; and to afford time for these, discussions on the physiology and pathology of the nervous system were thrown into the demonstration.

The first lecture on the distribution of the nerves, was upon presenting a display of the *first, second, third, fourth, fifth, and sixth* nerves. It appeared incumbent on me

to remark, that between the opinions taught in the schools, and the inferences to be deduced from the distribution of these nerves, there was no correspondence. Why do six nerves pass into the orbit? Why should two nerves descend into the nose? Why should three nerves penetrate the coats of the eye? Why should some of these nerves have ganglions on them and others none? If it be correct, that the brain is the *officina spirituum*, and gives out a common influence through the nerves, what is the meaning of this intricacy in the distribution of the nerves? I then held the following argument. Common occurrences, and the symptoms of disease, correspond with the anatomical facts, while they are adverse to the received opinions.

1. A catarrhal inflammation of the membrane of the nose is attended with the loss of the sense of smelling, and the increase of the sensibility to common irritation. Does not this imply a difference in the functions of the first and of the fifth nerve? and that their offices are not transferable?

2. In performing the operation of couching the cataract, as the needle touches the surface of the eye, it pricks it, and the patient feels a pain similar to what he would do were the skin pricked; but as the needle passes through the retina, he has a flash of fire. Does not this imply a difference of sensibility from the same injury, or the same impulse? Do we not perceive that there is a nerve of vision, and a nerve appropriated to the external surface?

3. When we receive a blow on the head, does not the same vibration affect the nerves of sense differently? In the ear, it produces sound as of the ringing of bells; in the eye, coruscations of light.

4. But here is the third nerve passing into the eye; is it also for sensation, or is there a motion of the iris to be established in relation to the sensorial impressions?

5. Shall we admit the interpretation, that the brain is the common sensorium, and that the peculiar office and sensibility of the external organ of sense result from the organization of the extremity of the nerve? On the contrary, it is capable of proof, that the trunk of a nerve, even of sense, receives and conveys an impulse which gives rise to the ideas belonging to that sense and to no other. The agony which accompanies the extirpation of the eye, forbids us to expect an account of the sensation experienced when the optic nerve is cut across. But we have other proofs. When the pudic nerve is exposed, the sensation is that which is appropriate to the glans.

The subject was followed up in the succeeding lecture; which, in order, was a demonstration of the nerves of the tongue—where three nerves are given to one organ.

Such, then, were the suggestions from anatomy and common experience, which led me to the conclusion, that nerves have appropriate properties; and that these properties are derived from the roots of the nerves, that is, their origins in the brain. To verify this view, I was first led to make experiments on the brain. These proved futile; and I then thought of determining the matter by experiments on the spinal marrow, and the roots of the spinal nerves.

The Society must perceive, that when it was demonstrated that the anterior and posterior roots differed in function, the whole investigation became anatomical. Tracing the column of the spinal marrow which gives rise to the anterior roots, upwards, we meet with the ninth, sixth, and third, arising from the same tract; and as these are distributed to muscles exclusively, we must infer that they are motor nerves; thus confirming the deductions from the experiments, that the whole anterior column gives off only nerves of motion.

It must likewise be obvious how these investigations into the functions of the spinal nerves, their roots and columns, carried me back to the original field of inquiry, the cerebral nerves; and this conducted me to the observation, that the fifth pair of the brain is analogous, in the structure of its roots, and its functions, to the spinal nerves.

The next subject to which I request the indulgent attention of the Society, regards those nerves, which in a paper delivered in 1821, I called

The Respiratory System of Nerves.

I foresaw that my views on this subject would prove embarrassing to physiologists. But the length of time that has elapsed, and the ingenuity of many men who have engaged in the investigation, have made it ripe for further inquiry.

In the paper alluded to, certain nerves, very distinct from the thirty spinal nerves and fifth pair, which from their uniformity of origin and course I called regular nerves, were pointed out. These nerves also bore distinct features from the nerves of the encephalon. They were the *portio dura* of the seventh nerve, the glossopharyngeal nerve, and the spinal accessory nerve; to which I added the diaphragmatic, and external respiratory nerve.

As these nerves are peculiar in their origins, so are they in their course and distribution. On the outside of the *corpus olivare*, and anterior to the *processus ad cerebellum*, when the pia mater is torn away, a tract, marked by the size of the holes from which the nourishing vessels have been withdrawn, and continued downwards behind the *ligamenta denticulata*, is perceived; from the upper part of this column these nerves arise conspicuously, and from this they diverge as from a centre. They differ in length, and perhaps in importance; but they go to every part, throughout the extended frame, associated in the act of respiration, or in the many lesser actions in which the organs of respiration participate.

Another circumstance was pointed out as marking their peculiarity. When sense and volition are lost, and the individual is dying, these nerves retain their power, and are the last to yield to the influence of death.

In marking the difference in these nerves from the regular spinal nerves and fifth pair, we may add to their peculiar mode of origin, the distinction in the columns from which they arise. The peculiarity of the columns which give origin to the regular nerves is their decussations: but such decussations are not found in the columns which give off the respiratory nerves.

Let us be distinct. There are two anterior or motor columns in the spinal marrow; and two, more posteriorly situated, sensitive columns. These resemble each other in this, that they respectively interchange filaments, the anterior columns with each other, and the posterior columns with each other.

No other columns of the spinal marrow make this interchange; and the respiratory columns are far apart.

It is not unnatural to conclude that such interchange is necessary to the infinite varieties in the associated actions of the frame, where sensation and voluntary motion are in operation; whilst the uniformity of the respiratory act requires no such provision. At all events, the respiratory nerves arise from columns which do not decussate, a circumstance which distinguishes the systems.

It was an early object with me, to make out the connexion between the roots of the diaphragmatic nerve and of the spinal accessory nerve. I conceived that as these nerves were closely united in office, the latter elevating the shoulders, so as to assist in the due expansion of the chest, while the former excites the diaphragm*—for the expansion of the chest is necessary to the full action of the diaphragm—they might have the same origin. But independently of anatomical investigation, and waiting for those occurrences in practice which are perhaps better than experiment, symptoms seem to confirm the correctness of this view.

In the case already alluded to, of disease in the bodies of the cervical vertebræ, and which I have selected from among others, merely because at the time of writing it is a subject of daily inspection, the common muscular motions of the neck and arms are entirely suspended, whilst the breathing is not, and never has been affected. The arms hang like empty sleeves, the head falls forward, if not supported with the hand or by an instrument, the muscles are wasted, and the neck thin; yet in breathing, the mastoid muscle and the trapezius muscle swell and become as firm as a piece of board.

Anatomical investigation shows the roots of the spinal accessory nerve arising far apart from the muscular roots of the nerves of the arms: indeed they are more nearly allied to the roots of sensation than of motion; and in the instance above, we find common muscular actions cut off, and those of respiration perfect. We see the sensibility in the whole extent of the respiratory passages, and the influence of the will retained, through the respiratory nerves. The same phenomena are presented in the common case of hemiplegia.

Such facts countenance the view which was presented to the Society, where a peculiar office was ascribed to these nerves, and a distinct name given to them.

But there remain some questions of great difficulty and much interest. And I am now happy in taking the assistance of the experiments made by various ingenious gentlemen.

* Some have supposed that the diaphragm expands the chest laterally; an effect which I cannot conceive possible.

When the dissected body exhibits to us this extensive class of respiratory nerves, traceable from a centre to all the organs of respiration, a question arises, by what means do the sensibilities of the pharynx, larynx, lungs, stomach, bring these respiratory nerves and muscles into action? Is the system which we have been considering complete in itself? Are these respiratory nerves both sensitive and muscular? Are the necessary sensations propagated along sensitive nerves bound up with the muscular respiratory nerves, or do they owe their sensibility to the numerous connexions with the regular nerves formed in their course?

That a regular nerve may animate the whole class of respiratory nerves is demonstrated in the office of the fifth, in the Schneiderian membrane. The sensibility of the cavities of the nose bestowed by the branches of the fifth nerve, excites the act of sneezing.

But, on the other hand, if we place confidence in the experiments of VALENTIN on the roots of the *Vagus*, it is purely the central sensitive nerve of the respiratory system; for having exposed its roots, and taken them off from the side of the *medulla oblongata*, and at the same time having separated them from the roots of the glosso-pharyngeal nerve and spinal accessory nerve, he irritates these roots of the vagus, and finds no consequent action in the pharynx, stomach, or respiratory muscles: no motion is produced.

But again, taking the trunk of this nerve, where it lies in the neck, all the connexions of the nerve being entire, the irritation of it produces muscular actions, and the act of respiration is imitated.

There is no doubt that the *nervus vagus* is a sensitive nerve. When I have examined the abdomen of a man completely paralytic from disease, or from fracture of the vertebræ high up, the patient, though outwardly insensible below the neck, has felt when I pressed the stomach.

Again, with respect to the glosso-pharyngeal nerve, the experiments of Dr. REID go to prove it a sensitive nerve. It is impossible to cavil at these experiments. They were often repeated, and with a perfect understanding of the subject. He first finds that pinching the nerve gives pain. He then divides the nerve, and irritates the divided portion next the brain, by which muscular movements are produced in the throat.

I am well aware that, dissecting deep among nerves, the experimenter is subject to be mistaken; and in surgical operations on the human body, the exposed trunks of nerves give little pain, compared with the fine sensibility of their extremities. We find experiments by different hands giving different results, and the same experiments differing on one day from another, performed by the same person.

But the force of evidence is all in favour of the *nervus vagus* and the *glosso-pharyngeal* nerve being sensitive. And Dr. REID's experiments give a perfect example of what I have called the *Nervous Circle**; the sensibility or nervous influence flow-

* Phil. Trans. 1826. p. 163.

ing towards the origin of the nerve, to be returned by parallel nerves upon the muscles: for the uniformity of nature's laws is maintained in both the great systems, the regular, and the respiratory.

Experiments countenance another early conclusion. Of the three conspicuous nerves of this system which have been associated under the name of the eighth pair of nerves, the spinal accessory nerve is proved to be the essential muscular nerve. The experiments of Professor MÜLLER, Drs. REID and VALENTIN, exhibit this nerve as purely muscular.

I drew this conclusion when I presented to the Society the plan of the respiratory nerves and muscles. I suggested that the roots of the spinal accessory nerve and of the diaphragmatic nerve arose from the same portion of nervous matter: and that whilst the one went directly, and by the shortest way to the diaphragm, the other proceeded upwards, entered the head, and came down in association with the other nerves, in order, by these communications, to unite the motions of the air-tubes with the play of the chest in respiration, and that the whole respiratory apparatus might consent in action. Often as I have set my young friends to determine the question by dissection, I have found them puzzling and giving up the pursuit. No doubt the dissection is difficult; and we must still rest satisfied with a process of reasoning. The influence of these nerves is necessary to each other. The muscles of the chest and the diaphragm continue in action when the motions of the arm and of the muscles of the neck are lost. These nerves and their respective muscles continue in office when both sense and motion are gone.

In making two distinct systems of the nerves arising from the spinal column, it was never my intention that it should be believed that they were cut off from the sensorium. The connexion of the brain with the spinal marrow is a distinct subject of inquiry.

We know that concatenated motions can be excited in the body where there is no brain. We know that the action of respiration will continue when the brain is taken away; so far, then, it is obvious that the relations of the frame, whether for the purpose of locomotion and action, or of breathing, are perfect, independently of cerebrum and cerebellum. The question remains, what is the nature of that relation, or of that influence, maintained by the brain over the nervous system of the body? However that connexion may hereafter be found to be established, it will not invalidate the conclusions as to the unity of office of the nerves employed in respiration, and in the actions where the respiratory apparatus is brought into play.

Before concluding this subject, it is pertinent to notice, that writers have been led to attribute the entire action of respiration to the sensation in the lungs. To a certain degree this is undoubtedly true. When I formerly stated, that upon dividing the *par vagum* (and with it the sympathetic nerve), and cutting through the spinal marrow, the act of respiration continued, I established the fact that there was a source of motion in the respiratory organs independently of any sensation in the lungs. I

may be permitted to doubt, if in common breathing there is any sensation ; we are certainly not conscious of it. It cannot at least be anything like the exercise of sensibility of which we are conscious, and which is wearied and exhausted by repetition. There is then, we must apprehend, another source of the regulated drawing of breath, which excites the respiratory muscles not to occasional and sudden actions, but to the constant combined action of opening the passages to the air. Even in the decapitated head, this influence will cause the muscles of the nostrils to be drawn repeatedly, as in natural breathing*.

Of the Supply of Blood to the Nerves of the Respiratory System.

We have seen that the lateral part of the *medulla oblongata* and cervical part of the spinal marrow are more necessary to life than the brain itself ; that as on this part and the nerves thence arising, the actions of respiration depend, the phenomena of life depend more directly upon them than on any part of the animal body.

It being at the same time perfectly well understood, that no quality of brain or nerve, or vital property in any part, can exist without a supply of arterial blood, it becomes an object of interest to know how nature has provided for a bountiful arterial circulation to these important organs.

Our books, in treating of the circulation in the brain, state that the supply of blood to it is very much greater than to any other part of equal weight. This is correct, and would of itself mark the importance of the organ. But in proceeding to show how this is accomplished, they state, that four great arteries ascend to the brain, and that of these the vertebral arteries, for greater security against the supply of blood being dangerously diminished, ascend through the foramina in the cervical vertebræ. We object to this last conclusion.

It is not to secure the free circulation through the brain that the vertebral arteries take this tortuous and concealed course. It is for the supply of arterial blood to these vital nerves, and to that part of the spinal marrow which gives origin to them.

This idea suggested itself to me, on observing, in a subject minutely injected, with what a copious supply of tortuous arteries these nerves and the side of the *medulla oblongata* were surrounded. When these arteries, branches of the vertebral artery, and their accompanying veins were removed, we saw the foramina by which they enter into the respiratory column conspicuous beyond what is seen in other parts.

This opinion was pointed out in a former paper† ; but the subject acquires a higher interest from the observations of Sir ASTLEY COOPER. He found that, on compressing the vertebral arteries at the lower part of the neck, where they are about to enter

* The head gasps in successive actions after decapitation.—LEGALLOIS. Breathing continued after the pithing of the animal in the cervical region, and after the brain and cerebellum had been removed and the vagi divided in the neck.—Dr. REID. “I have seen the respiratory muscles twice called into simultaneous movement after all the thoracic viscera had been rapidly removed,” &c.—Dr. REID.

† See the Nervous System, p. 119.

the canal of the bone, the animal ceased to breathe. It did not die like an animal suffocated by compression of the windpipe, but there came a gradual subsidence of the motion of respiration, evincing that the source of activity and of sensibility in the centre of the respiratory system was withdrawn.

Practically considered, this is a subject of interest. Are we not daily seeking for the cause of sudden death in organs, the condition of which cannot explain the phenomena; for example, the heart and brain? The pathologist is satisfied when he finds the heart in a slight degree removed from a condition of health; and yet he must be aware that when wounded or deeply diseased, death is protracted: there is the agitation of dying, the labour of these organs of respiration. It is only in violent injury, which shall affect the centre of the respiratory system, that there is no act of dying, but a sudden cessation of all action. The bruiser, on receiving a blow on the throat, or a blow on the stomach unexpectedly, is killed, as by the *coup-de-grace* given to the malefactor broken on the wheel. He dies instantly without a sigh, and without a motion of the features indicative of agony.

Are not these instances of injury propagated to the centre of the nerves of this system, on which the vital action of respiration and expression depend? The cause is equal to the effect; while death from organic lesion in the thorax, is attended with symptoms, with suffering, more or less prolonged, *with the act of dying*.